Description of Proposed Revision of Handbook on: Propagation Effects for Land Mobile Satellite Systems

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1. Introduction

The Applied Physics Laboratory, The University of Texas at Austin, JPL, and NASA are exploring the need for revising the Handbook on Propagation Effects for Land Mobile Satellite Systems published as NASA Reference Publication 1274 in February 1992 (Figure 1). The original publication was an outgrowth of a series of joint mobile propagation experiments performed by the Electrical Engineering Research Laboratory of The University of Texas at Austin and the Applied Physics Laboratory of The Johns Hopkins University between 1983 and 1988. When published, the text served the purpose of providing a state of the art manual describing experiments, results, concepts, and models associated with propagation effects for land mobile satellite scenarios. Investigations were cited from within and outside the United States. Although published in 1992, the text contains only referenced material through 1991. Since this time, a number of other mobile satellite experiments and modeling efforts have been performed throughout the world. In addition, new areas of investigation such as personal access and mobile-aeronautical communications have approached a level of maturity and importance requiring descriptions of propagation effects. The intent of the proposed effort is therefore to revise the manual such that it contains pertinent new information, to broaden its scope by adding new subject material, and to delete outdated material (Figure 2).

2. Contents of Talk

The elements of the talk are summarized in Figure 3. To establish a common reference point, the major topics contained in the present text will first be reviewed. As a demonstration of the need for revising the previous text, examples of some pertinent mobile satellite experiments performed and modeling results obtained since 1991 will be cited. A suggested title will be proposed and a summary of the type of new material to be included in the revised text will be given.

3. Review of Salient Subjects in Existing Handbook

In Figures 4-6 are given the salient topics contained in the present mobile satellite handbook where each bullet constitutes an individual chapter. The first theme (Figure 4) cover-cd in the text deals with attenuation]) due to individual trees. The path attenuation and attenuation coefficient duc to tree canopies arc derived for static scenarios and are given at UHF (870 MHz) and L-Band (1.5 GHz). A scaling factor valid from UHF to L-Band is also presented along with a formulation characterizing the attenuation effects due to trees with and without foliage. The second theme given in Figure 4 deals with attenuation due to roadside trees. In this chapter the empirical roadside shadowing model is presented. This model describes the percentage of the distance traveled with fades greater than designated levels. The roads arc assumed to be lined with trees, the frequency ranges from UHF to S-hand, the elevation angles arc from 20° to 60°, and percentages range from 1% to 20%. Also given is a formulation describing the attenuation effects of foliage versus bare tree conditions at UHF (870 MHz). A scaling factor is presented here for mobile satellite scenarios valid over the frequency range UHF (870 MHz) to S-Band (3 GHz).

The next theme presented (Figure 5) deals with fading due to multi-path for both mountain and tree environments. Cumulative fade distributions arc presented where line-of-sight between the source and the receiver was generally maintained. The next bullet in Figure 5 corresponds to a chapter where cumulative distributions at L-Band are presented for fade and non-fade durations and for phase spreads. The distributions were obtained from tree shadowing mobile-satellite scenarios. Results are presented in a following chapter which give the cross polarization isolation at 1.5 GHz as a function of co-polarization fade at equal probability levels. Also given are results pertaining to repeat measurements where high and low gain receiving antennas were used. Also presented arc the results of a simulation based on real data of a space diversity scenario where two antennas on the vehicle are presumed to be located at different spacings. Diversity improvement factor and gains are described.

A Chapter (Figure 6) is presented reviewing, investigations from other countries such as Australia, Canada, Belgium, England, arid Japan. 1 n a subsequent chapter, modeling aspects arc covered associated with both empirical and theoretical results. This is followed by general conclusions and recommendations for follow-on efforts.

4. Examples of Land-Mobile Satellite Experiments Since 1991

Figures 7 through 12 give examples of pertinent investigations which provide new information. Although, these examples represent only a small sampling of investigations performed since 1991, they reinforce the rationale for updating the present mobile satellite handbook. In 1995 Vogel and Goldhirsh published results pertaining to low elevation angle mobile measurements (7°- 14°) at L-Band made in the western part of the United States using the MARECS B-2 satellite (Figure 7). Both multipath effects and tree shadowing of low-elevation angle measurements arc covered in this paper. In 1995, Goldhirsh and Vogel published a paper describing the Extended Empirical Roadside Shadowing (EERS) model which was an outgrowth of measurements in Central Maryland, Texas, the western United States, and Alaska (Figure 8). This model extends the results of the previous Empirical Roadside Shadowing (ERS) model such that the following are applicable: (a) the frequency range is between

870 MHz and 20 GHz, (b) the elevation angle range is '*i*" and 60°, and (c) the probability of fading is 1 % to 80%. The attenuation effects of foliage versus no foliage conditions are. modeled in this paper and arc demonstrated to be dramatically different from the effects at 870 MHz.

Gargione et al. in 1995 reported on the JPL ACTS mobile terminal (Figure 9). In this publication, fade distributions at 20 G Hz are presented for a rural free-way run and a suburban road characterized by rolling hills and roadside foliage. Butt et al. in 1995 reported on an extension of the ERS model in elevation angle from 60° to 80° (Figure 10). In 1995, Murr et al. reported on a European Space Agency investigation involving a tracking antenna receiving an 18.7 GHz signal from ITALSAT (Figure 11). Measurements were performed in the Netherlands, France, Germany, and Austria for different driving scenarios at elevation angles between 30°-35° and satellite azimuths of 0°, 45°, and 90". Driving scenarios included open rural, tree shadowed, suburban, and urban mixed.

In 1993, Obara et al. reported on land-mobile satellite propagation measurements at 1.5 GHz using the ETS-V satellite. Measurements were predominantly carried out along major expressways connecting cities as well as along several rural roads (Figure 12). The authors give cumulative fade, fade duration, and non-fade duration distributions for the individual roads traveled.

5. Summary of Revisions

In Figures 13-15 is given a summary of suggested revisions for the mobile-satellite handbook. This listing is at present preliminary and is expected to be modified based on feedback from the mobile-satellite community. The present, title of the text is "Propagation Effects for Land Mobile Satellite Systems: overview of Experimental and Modeling; Results." A suggested revised title is "Propagation Effects for Vehicular and Personal Mobile Satellite Systems: Overview of Experimental and Modeling Results." As the title suggests, the revised text will cover additional mobile platforms corresponding to air, marine, and personal (Figure 13).

The revised handbook will contain pertinent land-mobile satellite results obtained since 1991 (Figure 14). These include a description of experiments and new theoretical and empirical models. Revisions of models previously described will also be included. These revisions will include extensions of the frequency range, elevation angle, and probability range. A review of existing information in the handbook will also be made, and non-relevant material will be removed.

New subject material will also be added (Figure 15). This includes an overview of material accepted as recommendations by the International Telecomunnication Union-Radiocommunication (ITU-R). Propagation experiments involving delay spread spectrum measurements will be covered. New methodologies for arriving at mobile results will also be added. These will include optical procedures pursued by the University of Texas at Austin. The scope of the text will also be broadened such that it includes propagation effects associated with personal, marine, and aeronautical scenarios.

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Figure 1

Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results

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NASA

Figure 2

Background and Rationale for Revising Text

- Outgrowth of mobile propagation experiments between 1983 and 1988
  - UOT and JHU
- Text provided state-of-art experimental results, concepts, and models
- Text contains material only through 1991
- Many additional experiments and results published since 1991
  - New and revised results should be added
- Scope of text broadened
- Outdated results should be deleted

Figure 3

Contents of Talk

- Review major topics of present mobile-satellite handbook
- Examples of pertinent land-mobile satellite experiments and results since 1991
- Summary of modifications
  - – Suggested title
  - – Revisions of existing subject material
  - – New subject material in revised **text**
    - Scope broadened

Figure 4

Topics in Present Handbook (NASA Ref. Pub. 1274- Feb. 1992)

- Attenuation due to individual trees-static case
  - UHF (870 MHz) and L-Band (1.5 GHz)
  - Attenuation and attenuation coefficient
  - L-Band versus UHF scaling factor
  - Effects of foliage
- Attenuation due to roadside trees: mobile scenarios
  - Empirical Roadside Shadowing (ERS) model
  - Effects of foliage
  - Frequency scaling

Figure 5

Topics in Present Handbook (NASA Ref. Pub. 1274- Feb. 1992) (Continued)

- Signal degradation for line-of-sight communications
  - Multipath for mountain and tree environments
- Fade and non-Fade durations and phase spreads
  - cumulative Distributions
- Propagation effects due to cross polarization, antenna gain, and space diversity
  - Frequency re-use
  - Low and high gain antenna effects
  - Diversity improvement factor
  - Diversity gain

Figure 6

Topics in Present Handbook (NASA Ref. Pub. 1274- Feb. 1992) (Continued)

- Investigations from different countries
  - Australia, Canada, Belgium, England, United States, Japan
- Modeling for LMSS scenarios
  - Background concepts used in modeling
  - Empirical regression models
  - Probability distribution models
  - Geometrical-analytical models
- General conclusions
- Recommendations for follow-on efforts

Figure 7

Examples of Land-Mobile Satellite Experiments Since 1991

- Low Elevation Angle Measurements at L-Band
  - 1995, Vogel and Goldhirsh
    - IEEE Journal on Selected Areas in Communications, Vol. 13, No. 2, Feb. 1995
    - Multipath and tree shadowing effects in western U.S.A. using MARECS B-2 satellite
    - Elevation angles 7° to 14°

Figure 8

Examples of Land-Mobile Satellite Experiments Since 1991 (Continued)

- Extended Empirical Roadside Shadowing Model (EERS)
  - – Goldhirsh and. Vogel, 1995
    - Space Communications, Vol. 13, No. 3, 1995
    - Reviewed ACTS mobile results in central MD, Texas, and Alaska
    - Extended ERS model to 20 GHz
    - Extended ERS model to probability of 80%
      - – O dB fade
    - . Extended ERS model to elevation angle = 7 degrees
    - Effects of foliage at 20 GHz

Figure 9

Examples of Land-Mobile Satellite Experiments Since 1991 (Continued)

- Mobile Experiments Using ACTS
  - 1995, Gargione et al.
    - Space Communications, Vol. 13, No. 3, 1995
    - JPL-ACTS mobile terminal results
      - Cumulative distribution for rural freeway and suburban road at 20 GHz

Figure 10

Examples of Land-Mobile Satellite Experiments Since 1991 (Continued)

- Modelling the Mobile Satellite Channel for Communication System Design
  - Butt et al., 1995
    - . 9th International Conference on Antennas and Propagation, Eindhoven, The Netherlands
    - Extended ERS model from 60° to 80°

Figure 11

Examples of Land-Mobile Satellite Experiments Since 1991 (Continued)

- Land Mobile Satellite Narrowband Propagation Campaign at Ka Band
  - Murr et al., 1995
    - IMSC 95, Ottawa, Canada, June 6-8 1995
    - ESA funded investigation
    - Mobile measurements at 18.7 GHz using ITALSAT
    - Open rural, tree-shadowed, suburban, urban, mixed
    - Netherlands, France, Germany, Austria
      - Fade distributions for different azimuth pointing (O”, 45°, 90°)

Figure 12

Examples of Land-Mobile Satellite Experiments Since 1991 (Continued)

- Land Mobile Satellite Propagation Measurements in Japan Using ETS-V Satellite
  - Obara et al., 1993
    - IMSC, 1993, Pasadena, CA, June 16-18, 1993
    - ETS-V at 1.5 GHz at 40°-50°
    - Measurements in Japan
    - Major expressway measurements (4000 km)
    - Fade and fade duration distributions

Figure 13

Summary of Revisions (Preliminary)

- Old Title
  - Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results
- New (Suggested) Title
  - Propagation Effects for Vehicular and Personal Mobile Satellite Systems: Overview of Experimental and Modeling Results

    Land--mobile

    Personal mobile

    Air--mobile

    Marine-mobile

Figure 14

Summary of Revisions (Preliminary) (Continued)

- Revision of existing subject material
  - Add pertinent land-mobile satellite results since 1991
    - Experiments
    - New Models
      - Theoretical
      - Empirical
  - Update existing models
    - Frequency
    - Elevation angle
    - Probability range
    - Shadowing types
  - Deletions of non-pertinent material

Figure 15

Summary of Material to Be Added to Revised Text (Preliminary)

- Review ITU-R models
- Wideband propagation effects
    - Delay spread experiments
- New methodologies for arriving at mobile propagation results
    - Optical methods (University of Texas)
- Experiments and propagation effects pertaining to:
    - Aeronautical-mobile satellite
    - Personal-mobile satellite
    - Marine-mobile satellite